CLAIMS:

1. A method of achieving transmit diversity gain for frequency selective fading channels in a communication system having a base station with multiple transmit antennae and a mobile terminal with at least a single receive antenna, the method comprising the steps of:

providing a signal to be transmitted $s(n)$;

space-time encoding the signal $s(n)$ to produce at least two separate signals $s_1(n), s_2(n)$, each on a respective output;

feeding each output signal $s_1(n), s_2(n)$ to a zero-forcing pre-equaliser having a respective function $g_1(k)$, $g_2(k)$ to produce an output signal $x_1(n)$, $x_2(n)$;

feeding the output signal $x_1(n)$, $x_2(n)$ of each pre-equaliser to a transmit antenna;

transmitting the output signals $x_1(n)$, $x_2(n)$ over respective physical channels $h_1(k)$, $h_2(k)$;

receiving the output signals $x_1(n)$, $x_2(n)$ at at least a single receive antenna; and

space-time decoding the received signals, wherein

the functions $g_1(k)$, $g_2(k)$ of the zero-forcing pre-equalisers are selected such that the channel responses $g_1(k)*h_1(k)$, $g_2(k)*h_2(k)$ of the respective physical channels $h_1(k)$, $h_2(k)$ are flat fading channels.

2. A method according to Claim 1, wherein the communications system is a time-division duplex system and the method includes the further step of deriving the real channel coefficients from uplink channel coefficients for use in selecting the functions $g_1(k)$, $g_2(k)$ of the pre-equalisers.

3. A method according to Claim 2, wherein the step of deriving the real channel coefficients from uplink channel coefficients uses training symbols from the uplink channel.

4. A method according to Claim 2, wherein the step of deriving the real channel coefficients from uplink channel coefficients uses blind techniques.

5. A method according to Claim 1, wherein the communications system is a frequency-division duplex system and the method includes the further step of deriving the real channel coefficients by sending a set of training symbols to the receive antenna of the mobile terminal, the mobile terminal estimating the real channel coefficients and feeding back channel coefficient information to the base station.

6. A base station with multiple transmit antennae for communicating with a mobile terminal having at least a single receive antenna over physical channels $h_1(k)$, $h_2(k)$, the base station comprising:

a space-time encoder having an input of a signal to be transmitted $s(n)$ and at least two outputs each producing a separate signal $s_1(n)$,$s_2(n)$;

at least two zero-forcing pre-equalisers, each fed by a respective output signal $s_1(n)$,$s_2(n)$ and having a respective function $g_1(k)$, $g_2(k)$ to produce an output signal $x_1(n)$, $x_2(n)$; and

at least two transmit antennae, each being fed by the output signal $x_1(n)$, $x_2(n)$ of a respective one of the pre-equalisers, wherein the functions $g_1(k)$, $g_2(k)$ of the zero-forcing pre-equalisers are selected such that the channel responses $g_1(k)*h_1(k)$, $g_2(k)*h_2(k)$ of the respective physical channels $h_1(k)$, $h_2(k)$ are flat fading channels.

7. A communications system comprising the base station of Claim 6 and a mobile terminal having at least a single receive antenna and a space-time decoder to decode the signals received from the base station.

8. A method of achieving combined beamforming and transmit diversity for frequency selective fading channels in a communication system having a base station with multiple transmit antennae and a mobile terminal with at least a single receive antenna, the method comprising the steps of:

providing a signal to be transmitted $S(n;k)$;

space-time encoding the signal $S(n;k)$ to produce at least two separate signals $S_1(n;k)$,$S_2(n;k)$, each on a respective output;

feeding each output signal $S_1(n;k)$,$S_2(n;k)$ to a transmit processor to produce an output signal $X_1(n;k)$, $X_2(n;k)$;

applying respective selected transmit beamforming weights to each output signal $X_1(n;k)$, $X_2(n;k)$;

feeding the respective weighted signals to a signal combiner to perform a summing function of the signals and produce a signal X(n;k) for transmission;

feeding the summed signal X(n;k) to each of the multiple transmit antennae for transmission;

transmitting the signals X(n;k) over physical channel h(n;k);

receiving the received signal Y(n;k) at at least a single receive antenna;

feeding the received signal Y(n;k) to a receive processor to produce an output signal; and

space-time decoding the received signal.

9. A method according to Claim 8, wherein the respective transmit beamforming weights are selected as the eigenvectors corresponding to the two largest eigenvalues of the downlink channel covariance matrix (DCCM) of the physical channels h(n;k).

10. A method according to Claim 8, wherein the physical channel h(n;k) consists of two time-delayed rays, $h_1(n;k)$ and $h_2(n;k)$, with delay $\Delta\tau$, the transmit

processors do not add cyclic prefixes and one of the output signals from the transmit processors is delayed by $\Delta\tau$ before the respective selected transmit beamforming weight is applied thereto.

11. A method according to Claim 8, wherein the physical channel h(n;k) consists of two time-delayed rays, $h_1(n;k)$ and $h_2(n;k)$, with delay $\Delta\tau$, the beamforming weights being chosen such that the delayed signal or its inverse fast Fourier transform (IFFT) only goes through one channel $h_1(n;k)$ between the base station multiple transmit antennae and the receive antenna, whilst the undelayed signal or its IFFT only goes through another channel $h_2(n;k)$ between the base station multiple transmit antennae and the receive antenna, thereby creating two different channels which can be space-time decoded to recover the transmitted signal.

12. A method according to Claim 8, wherein the physical channel h(n;k) consists of two time-delayed rays, $h_1(n;k)$ and $h_2(n;k)$, with delay $\Delta\tau$, the beamforming weights being chosen such that the average transmit SINR function at the base station is maximized for each ray.

13. A method according to Claim 8, wherein the physical channel h(n;k) consists of two time-delayed rays, $h_1(n;k)$ and $h_2(n;k)$, with delay $\Delta\tau$, the beamforming weights being chosen such that the average receive SINR function at the mobile terminal is maximized.

14. A method according to Claim 8, wherein the physical channel h(n;k) consists of two time-delayed rays, $h_1(n;k)$ and $h_2(n;k)$, with delay $\Delta\tau$, the beamforming weights for each ray are chosen as the principal eigenvector of the downlink channel covariance matrix (DCCM) corresponding to that ray.

15. A method according to Claim 8, wherein the physical channel h(n;k) consists of two time-delayed clustered rays, $h_1(n;k)$ and $h_2(n;k)$, with delay ψ, and maximum excess delay for the clusters $\Delta\psi$, the transmit processors have a cyclic prefix length of $\Delta\psi$ and one of the output signals from the transmit processors is delayed by ψ before the respective selected transmit beamforming weight is applied thereto.

16. A method according to Claim 15, wherein the beamforming weights are chosen such that the delayed signal or its inverse fast Fourier transform (IFFT) only goes through one channel $h_1(n;k)$ between the base station multiple transmit antennae and the receive antenna, whilst the undelayed signal or its IFFT only goes through another channel $h_2(n;k)$ between the base station multiple transmit antennae and the receive antenna, thereby creating two different channels which can be space-time decoded to recover the transmitted signal.

17. A method according to Claim 15, wherein the beamforming weights being chosen such that the average transmit SINR function at the base station is maximized for each clustered ray.

18. A method according to Claim 15, wherein the beamforming weights being chosen such that the average receive SINR function at the mobile terminal is maximized.

19. A method according to Claim 15, wherein the beamforming weights for each clustered ray are chosen as the principal eigenvector of the downlink channel covariance matrix (DCCM) corresponding to that clustered ray.

20. A method according to Claim 15, comprising the further steps of:
estimating a power-delay-DOA profile for channel $h(n;k)$; and, based on the profile: determining the cyclic prefix, $\Delta\psi$, to be added by the transmit processors; determining the delay ψ; diversity order and modulation scheme; and determining the transmit beamforming weights.

21. A method according to Claim 20, comprising the further step of estimating the downlink channel covariance matrix (DCCM) from the uplink channel covariance matrix (UCCM) to construct transmit beamforming weights.

22. A method according to Claim 21, comprising the further step of determining the diversity order and modulation scheme based on the profile.

23. A method according to Claim 8, wherein the transmit and receive processors are selected from the group consisting of: OFDM, MC-CDMA MC-DS-CDMA and a single carrier system with cyclic prefix.

24. A base station with multiple transmit antennae for communicating with a mobile terminal having at least a single receive antenna over physical channel $h(k)$, the base station comprising:
a space-time encoder having an input of a signal to be transmitted and at least two outputs each producing a separate signal;
at least two transmit processors each receiving one of the outputs from a respective space-time encoder;
at least two transmit beamformers each receiving an output from a respective transmit processor and applying a transmit beamforming weight thereto;

a signal combiner receiving signals from the beamformers and operable to perform a summing function of the signals from the beamformers and produce a signal for transmission by the multiple transmit antennae.

25. A base station according to Claim 24, wherein the physical channel h(n;k) consists of two time-delayed rays, $h_1(n;k)$ and $h_2(n;k)$, with delay $\Delta\tau$, further comprising a delay of $\Delta\tau$ interposed between one of the multiple access transmit processor outputs and a beamformer to delay the signal output from the transmit processor by $\Delta\tau$ before the respective selected transmit beamforming weight is applied thereto, wherein the transmit processors do not add cyclic prefixes.

26. A base station according to Claim 24, wherein the physical channel h(n;k) consists of two time-delayed clustered rays, $h_1(n;k)$ and $h_2(n;k)$, with delay ψ, and maximum excess delay for the clusters $\Delta\psi$, further comprising a delay of ψ interposed between one of the multiple access transmit processor outputs and a beamformer to delay the signal output from the transmit processor by ψ before the respective selected transmit beamforming weight is applied thereto, the transmit processors having a cyclic prefix length of $\Delta\psi$.

27. A base station according to Claim 24, further comprising a first processor to determine a power-delay-DOA profile estimate for channel $h(n;k)$; and, based on the profile, determine: the length, $\Delta\psi$, of the cyclic prefix to be added by the transmit processors; the delay ψ; diversity order and modulation scheme; and the transmit beamforming weights.

28. A base station according to Claim 27, further comprising a second processor to estimate a downlink channel covariance matrix (DCCM) from the

uplink channel covariance matrix (UCCM) to construct transmit beamforming weights.

29. A base station according to Claim 15, wherein the transmit and receive processors are selected from the group consisting of: OFDM, MC-CDMA MC-DS-CDMA and single carrier system with cyclic prefix.

30. A communications system comprising the base station of Claim 24 and a mobile terminal having at least a single receive antenna, a receive processor to produce an output signal and a space-time decoder to decode the output signal.

31. A method of achieving combined beamforming and transmit diversity for frequency selective fading channels in a communication system having a base station with multiple transmit antennae and a mobile terminal with at least a single receive antenna, the method comprising the steps of:

providing a signal to be transmitted $s(n)$;

space-time encoding a signal to be transmitted $s(n)$ to produce at least two separate signals $s_1(n)$,$s_2(n)$, each on a respective output;

delaying one of the space-time encoded output signals by $\Delta\tau$;

applying respective selected transmit beamforming weights to the delayed and undelayed signals;

feeding the respective weighted signals to a signal combiner to perform a summing function of the signals and produce a signal for transmission;

feeding the summed signal to each of the multiple transmit antennae for transmission;

transmitting the summed signals over the physical channel h(k);

receiving the major components of the transmitted signals at at least a single receive antenna at substantially the same time; and

space-time decoding the received signal.

32. A method according to Claim 31, wherein the physical channel h(k) consists of two time-delayed rays $h_1(k)$, $h_2(k)$ with delay $\Delta\tau$, the beamforming weights are chosen such that the delayed signal only goes through one ray $h_1(k)$ between the base station multiple transmit antennae and the receive antenna, whilst the undelayed signal only goes through another ray $h_2(k)$ between the base station multiple transmit antennae and the receive antenna.

33. A method according to Claim 31, wherein the physical channel h(k) consists of two time-delayed rays $h_1(k)$, $h_2(k)$ with delay $\Delta\tau$, the beamforming weights are chosen such that the average transmit SINR function at the base station is maximized for each ray.

34. A method according to Claim 31, wherein the physical channel h(k) consists of two time-delayed rays $h_1(k)$, $h_2(k)$ with delay $\Delta\tau$, the beamforming weights are chosen such that the average receive SINR function at the mobile terminal is maximized.

35. A method according to Claim 31, wherein the physical channel h(k) consists of two time-delayed rays $h_1(k)$, $h_2(k)$ with delay $\Delta\tau$, the beamforming weights for each ray are chosen as the principal eigenvector of the downlink channel covariance matrix (DCCM) corresponding to that ray.

36. A method according to Claim 31, wherein the physical channel h(k) consists of two time-delayed rays $h_1(k)$, $h_2(k)$ with delay $\Delta\tau$, the delay $\Delta\tau$ is derived from downlink channel information.

37. A method according to Claim 31, wherein the physical channel h(k) consists of two time-delayed rays $h_1(k)$, $h_2(k)$ with delay $\Delta\tau$, the delay $\Delta\tau$ is derived from uplink channel information.

38. A method according to Claim 31, wherein the physical channel h(k) consists of multiple rays with two major rays $h_1(k)$, $h_2(k)$ delayed by $\Delta\tau$, the beamforming weights are chosen such that the delayed signal only goes through one ray $h_1(k)$ between the base station multiple transmit antennae and the receive antenna, whilst the undelayed signal only goes through another ray $h_2(k)$ between the base station multiple transmit antennae and the receive antenna.

39. A method according to Claim 31, wherein the physical channel h(k) consists of multiple rays with two major rays $h_1(k)$, $h_2(k)$ delayed by $\Delta\tau$, the beamforming weights are chosen such that the average transmit SINR function at the base station is maximized for each ray.

40. A method according to Claim 31, wherein the physical channel h(k) consists of multiple rays with two major rays $h_1(k)$, $h_2(k)$ delayed by $\Delta\tau$, the beamforming weights are chosen such that the average receive SINR function at the mobile terminal is maximized.

41. A method according to Claim 31, wherein the physical channel h(k) consists of multiple rays with two major rays $h_1(k)$, $h_2(k)$ delayed by $\Delta\tau$, the beamforming

weights for each ray are chosen as the principal eigenvector of the downlink channel covariance matrix (DCCM) corresponding to that ray.

42. A method according to Claim 31, wherein the physical channel h(k) consists of multiple rays with two major rays $h_1(k)$, $h_2(k)$ delayed by $\Delta\tau$, the delay $\Delta\tau$ is derived from downlink channel information.

43. A method according to Claim 31, wherein the physical channel h(k) consists of multiple rays with two major rays $h_1(k)$, $h_2(k)$ delayed by $\Delta\tau$, the delay $\Delta\tau$ is derived from uplink channel information.

44. A base station with multiple transmit antennae for communicating with a mobile terminal having at least a single receive antenna over physical channel $h(k)$ having two time-delayed rays, $h_1(k)$ and $h_2(k)$, the base station comprising:

a space-time encoder having an input of a signal to be transmitted and at least two outputs each producing a separate signal;

at least two transmit beamformers each receiving an output from the space-time encoder and applying a transmit beamforming weight thereto;

a signal combiner receiving signals from the beamformers and operable to perform a summing function of the signals from the beamformers and produce a signal for transmission by each of the multiple transmit antennae, wherein a delay of $\Delta\tau$ is interposed between the space-time encoder and one of the beamformers such that the major components of the transmitted signals are received at at least a single receive antenna at substantially the same time.

45. A communications system comprising the base station of Claim 24 and a mobile terminal having at least a single receive antenna and a space-time decoder to decode the received signal.